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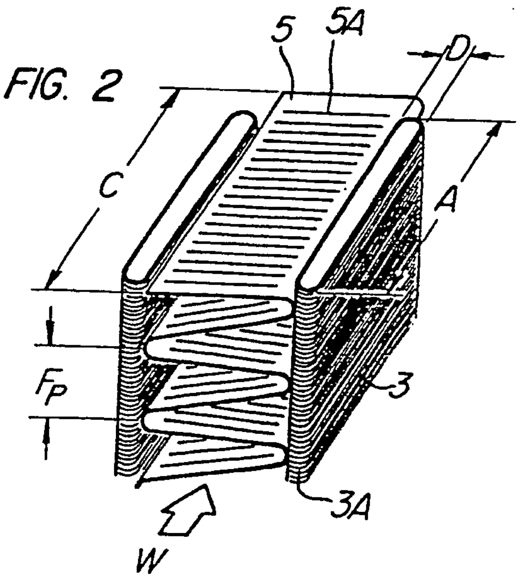
(54) Heat exchangers and methods of fabricating heat exchangers.

(57) In a heat exchanger including a flat tube (3) made of metal, and corrugated fins (5) joined by welding to the tube (3), a multiplicity of projections (3A) are successively formed on one side of the flat tube (3) and arranged in a direction intersecting the axis of the tube (3). The projections (3A), which may be triangular, arcuate, trapezoidal or any other suitable shape in cross section, each extend by a distance less than the thickness of a wall of the tube (3).

FIG. 2



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HEAT EXCHANGERS

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This invention relates to heat exchangers, more particularly, but not exclusively, for use as radiators for dissipating heat from the cooling water of engines of automotive vehicles. The invention also relates to methods of fabricating such heat exchangers.

The radiators of automotive vehicle engines have to withstand vibrations transmitted from the vehicle bodies and also internal pressure caused by a rise in the temperature of the engine cooling water. Thus the tubes of such radiators need to have high endurance strength.

To give sufficiently high endurance strength to the tube of the radiator, it has hitherto been customary to increase the thickness of the wall of the tube or reinforce the tube by attaching reinforcing members to portions of the tube that are low in endurance strength. These methods have disadvantages in that the material used is increased in volume, causing an increase both in the weight of the heat exchanger and the cost thereof.

US patent 2,011,854 discloses a corrugated fin type radiator including a flat tube formed on its outer surface with ribs or spherical projections. US patent 1,993,872 also discloses a corrugated fin type radiator including a flat tube formed on its surface with irregularities of a large size to increase the area of contact with corrugated fins. In these two radiators, the irregularities on the surface of the flat tube are of large size, so that difficulties would be encountered in bringing the irregularities of the tube into contact with the fins.

According to the present invention there is provided a heat exchanger comprising:

a tube of a flat cross-sectional shape formed of metal and permitting a heat exchanging medium to flow therethrough;

fins in thermal contact with said tube for promoting exchange of heat between the heat exchanging medium and a fluid; and

a multiplicity of projections formed on one side of said tube and arranged in a direction intersecting the axis of said tube, said projections each extending from said tube by a distance less than the thickness of a wall of said tube.

According to the present invention there is also provided a method of fabricating a heat exchanger comprising the steps of:

successively forming on a planar metal strip a multiplicity of projections each extending from said strip by a distance less than the thickness of said strip in such a manner that said projections are arranged in a direction intersecting the axis of said strip;

bending said strip with said projections into a cylindrical shape and then seaming the cylindrical body;

applying solder to the seamed cylindrical body and finishing the soldered cylindrical body in the form of a flat tubular body; and

joining by welding corrugated fins to said flat tubular body along its axis.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a front view of the heat exchanger comprising one embodiment of this invention;

Figure 2 is a perspective view of the heat exchanger shown in Figure 1;

Figure 3 is a sectional view of the tube of the heat exchanger shown in Figure 1, as viewed axially thereof;

Figure 4 is a schematic view of an apparatus for forming the tube of the heat exchanger shown in Figure 1;

Figures 5A to 5F are sectional views of the tube of the heat exchanger formed by the apparatus shown in Figure 4;

Figure 6 is a perspective view of a pair of first forming rollers of the apparatus shown in Figure 4;

Figure 7 is a sectional view of the tube formed by the apparatus shown in Figure 4;

Figures 8 and 9 are sectional views of modifications of the tube of the heat exchanger according to the invention, as viewed axially thereof;

Figures 10 and 11 are perspective views of other modifications of the pair of first forming rollers shown in Figure 6 of the apparatus shown in Figure 4;

Figures 12 to 14 are still other modifications of the tube of the heat exchanger according to the invention;

Figures 15 and 16 are sectional views of still other modifications of the tube of the heat exchanger according to the invention, as viewed peripherally thereof;

Figure 17 is a perspective view of an apparatus for forming the tubes

shown in Figures 15 and 16; and

Figure 18 is a perspective view of a further modification of the tube of the heat exchanger according to the invention.

Figure 1 shows in a front view one embodiment of the heat exchanger in conformity with the invention. The heat exchanger shown is used as a radiator of an engine of an automotive vehicle. The numeral 1 designates an inlet tank made of synthetic resinous material or brass for receiving engine cooling water through a cooling water inlet pipe 2 and distributing it to a tube 3. The inlet tank 1 is formed with an inlet port 4 for injecting the engine cooling water therethrough into the inlet tank 1. The numeral 5 designates corrugated fins thermally connected to the tube 3 along its length as by welding. The corrugated fins 5 and the tube 3 form a radiator core which is a heat dissipating portion of a radiator 6. The numeral 7 designates an outlet tank made of a synthetic resinous material or brass for collecting the engine cooling water which is led from the tank 7 through a cooling water outlet pipe 8 to an engine, not shown.

The tube 3 is formed by shaping a brass strip (having a thickness of 0.13 mm, for example) into a flat tube as shown in Figure 2. The flat tube 3 is arranged in such a manner that the longitudinal cross section of the tube 3 is parallel to an air current W supplied to the radiator 6 from a blower, not shown. Only one row is arranged with respect to the direction of air current as shown in Figure 2. Thus the width C of the corrugated fins 5 is not much different from the length A (major dimension) of the tube 3, so that the thickness of the radiator 6 can be greatly reduced. The tube 3 has a width D (minor dimension) which is about 2 mm. As shown in Figure 3, the tube 3 is formed with a multiplicity of projections 3A each forming the vertex of a triangle and arranged substantially perpendicular to the axis of the tube in strip form. The projections 3A each have a height B smaller than the thickness of the wall of the tube 3 and may be 0.02 mm, for example. The projections 3A are spaced apart from each other by a spacing interval Tp of about 0.87 mm.

A process for shaping the tube 3 will be described. In forming the tube 3, an apparatus shown schematically in Figure 4 is used. A metal strip 10 is paid out of a coil 9 of metal strip and supplied to a first forming roller group 11A, 11B, 11C and 11D which successively bends the metal strip 10 into shapes shown in Figures 5A to 5E. Of the first forming roller group

11A, 11B, 11C and 11D, the pair of rollers 11A disposed nearest the coil 9 is formed with elevations 11' as shown in Figure 6, so that the strip 10 is formed with the projections 3A when it passes between the rollers 11A.

The strip 10 is bent by the first forming roller group 11A, 11B, 11C and 11D into the shape shown in Figure 5E and then has its seam portion 10A (see Figure 7) compressed by seamer rollers 12. A second forming roller group 13 forms the strip 10 into the shape shown in Figure 5F.

The strip 10 thus seamed is introduced into a solder tank 14 to have a coat of solder applied thereto, and then introduced into a cooling tank 15 where the solder-coated strip 10 is suddenly cooled. Thereafter the strip 10 is supplied to a finishing roller group 16 which gives finishing touches to the strip 10 to give a desired shape to the tube 3. The tube 3 is cut into predetermined lengths in a cutting section 17, thereby completing the operation of forming the tube 3. The numeral 18 designates a pulse generator for controlling cutting of the tube 3 into the desired lengths in the cutting section 17.

The strip 10 is formed with the projections 3A by the first forming roller group 11A, 11B, 11C and 11D to provide the tube 3 with the projections 3A, so that a number of projections 3A are formed in the seam portion 10A. The presence of the projections 3A enables the solder to penetrate deep into the seam portion 10A when the strip 10 is introduced into the solder tank 14. In this type of seamed tube, a lack of solder in the seam portion 10A tends to cause leaks from the tube 3, and it has hitherto been customary to apply a coat of solder of a thickness greater than is necessary to ensure that the accident of cooling water leaks from the tube 3 does not occur. However, the presence of the projections 3A enables the seam portion 10A to be soldered with enough strength to prevent cooling water leaks from taking place by minimizing the amount of the solder used. This is conducive to increase strength of the tube 3 and reduced cost thereof.

Meanwhile the corrugated fins 5 are formed by shaping a strip of copper (having a thickness of 0.05 to 0.06 mm, for example) in such a manner that the fins have a spacing interval Fp of about 2.0 to 3.5 mm as shown in Figure 2. The fins 5 are each formed with a plurality of louvres 5A by cutting and raising the material at an angle of 20 to 30^{0}.

The corrugated fins 5 and the tube 3 are joined to one another as

follows. The tube 3 has a coat of solder applied to its surface as aforesaid. The lengths of tube 3 are assembled with the corrugated fins 5 by using a jig. The tube 3 and fin 5 assembly is placed in a furnace and heated to melt the coat of solder on the tube 3, so that the corrugated fins 5 are rigidly joined to the lengths of tube 3 by the molten solder.

As aforesaid, the tube 3 is formed with the projections 3A arranged in strip form. The height B of the projections 3A is only about 0.02 mm which is small as compared with the minor dimension D of the tube 3 and is smaller than the thickness of the wall of the tube 3. Thus no special attention need be paid to the positions of the projections 3A when the tube 3 is assembled with the corrugated fins 5.

The radiator 6 including the tube 3 and corrugated fins 5 assembled as described hereinabove has the advantage that the tube 3 has high bending rigidity by virtue of the presence of a multiplicity of projections 3A arranged in strip form. The tube 3 shown in Figure 3 was formed to have the projections 3A having a height B of 0.02 mm and a spacing interval Tp of 0.37 mm, and a tube formed with no projections was also formed. When the two types of tube were compared with each other, it has been found that the tube 3 formed with the projections 3A is 1.5 to 2.0 times as high in bending strength as the tube having no projections.

The values of the height B and spacing interval Tp of the projections 3A described hereinabove are given as one example. It has been ascertained that the tube 3 of high strength can be produced when the height B is in the range between 0.02 and 0.1 mm and the spacing interval Tp is in the range between 0.87 and 1.0 mm. Stated differently, if the height B of the projections 3A is smaller than the thickness of the wall of the tube 3, the minor dimension D of the tube will not show large variations depending on the position of the projections 3A. Consequently, no special attention need be paid to the position of the projections 3A when the corrugated fins 5 are joined to the tube 3, in obtaining satisfactory assembling of the fins 5 with the tube 3.

Thus in the radiator 6, the tube 3 has greatly increased strength. As a result, the tube 3 can have sufficiently high endurance strength to have a prolonged service life even if the thickness of the wall is reduced as compared with tubes of the prior art. This is conducive to material conservation and reduced cost.

Since the tube 3 can have its wall thickness reduced as compared with the wall thickness of tubes of the prior art, the amount of heat dissipated through the wall of the tube 3 is increased and the efficiency with which heat exchange takes place is increased. The provision of the projections 3A greatly increases the surface area of the tube 3, thereby also contributing to increased efficiency with heat exchange takes place through the wall of the tube 3.

The tube 3 has increased rigidity, so that the side of the tube 3 coming into direct contact with the fins 5 can be kept in a straight line without curving. Thus the fins 5 can be positively maintained in contact with the tube 3 along its entire length. This enables good transfer of heat from the tube 3 to the fins 5 to be obtained, thereby further increasing the efficiency with which heat exchange takes place through the tube 3.

In the radiator shown in Figure 2 in which the tube 3 is arranged only in one row with respect to the direction of flow of the air current W, the lengths of tube 3 necessarily have a large axial dimension. The provision of the projections 3A in the tube of a heat exchanger, such as the radiator 6 shown in Figure 2, has the great effect of increasing the strength of the tube 3.

Various modifications are of course possible.

More specifically, the projections 3A are each formed in Figure 3 as constituting the vertex of a triangle. However, the invention is not limited to this form of projections 3A, and each projection may constitute the top point of an arc as shown in Figure 8 or a trapezoid as shown in Figure 9. In each case, the projections 3A are of a shape such that the bending rigidity of the tube 3 can be increased.

In the embodiment, the projections 3A are formed by working the strip 10 from both sides thereof by means of the first pair of forming rollers 1A shown in Figure 6. However, the projections 3A may be formed by working the strip 10 only from one side as shown in Figure 10 and 11. In Figure 11, there is shown a modification of the embodiment in which large irregularities are formed in the seam portion 10A so that a large quantity of solder will penetrate deep into the seam portion 10A.

The projections 3A have been described as being formed on the entire periphery of the tube 3. In a tube of a flat cross-sectional shape, the side of the tube that is brought into contact with the fins shows a greatest

reduction in strength. Therefore, the projections 3A may be formed only on the side of the tube 3 that comes into contact with the fins 5.

The multiplicity of projections 3A have been described as being arranged in strip form in a direction perpendicular to the axis of the tube 3. However, the projections 3A may be arranged, as shown in Figure 12, in strip form in a direction oblique to the axis of the tube 3B, or, as shown in Figures 13 and 14, in wave form as in tubes 3C and 3D. In the modifications shown in Figures 12 to 14, the fins 5 are each joined to the tube 3 by straddling a plurality of projections 3A. However, since the height B of the projections 3A is small, the projections 3A are filled with solder on their undersides and a strong joint is formed thermally between the tube 3 and fins 5. By bringing the projections 3A into a position inclined with respect to the axis of the tube 3, the side of the tube 3 becomes completely flat, so that good contact can be obtained between the tube 3 and fins 5 and increased heat exchanging efficiency can be achieved.

The tube 3 has been described as being shaped by subjecting the strip 10 to seaming. However, the tube 3 may be first formed by drawing or welding without forming the seal portion 10A as in tubes 3E and 3F shown in Figures 15 and 16 respectively, and the projections 3A may be formed in the tube 3 as shown in Figure 17 after the tube 3 has been formed.

In Figure 17, the numeral 19 designates a stationary core for imparting a correct shape to the tube 3. The core 19 is inserted in the tube 3 which is held between rollers 20 for forming the projections 3A on its surface while being pressed into a flat shape. The tube 3F shown in Figure 16 is elliptic in cross section. The tube of a heat exchanger is generally very small in wall thickness. Even if the tube is elliptic in cross section like the tube 3F, the small wall thickness renders the side of the tube planar when the tube is assembled with the fins.

Brass has been described as being used for making the tube 3. However, the invention is not limited to a specific material for making the tube 3, and other suitable material, such as aluminium or stainless steel, may be used.

The spacing interval Tp between the adjacent projections 3A has been described as being smaller than the spacing interval Fp between the adjacent fins 5. However, even if the spacing interval Tp between the projections 3A is equal to or larger than the spacing interval Fp between the

fins 5, the effects described as being achieved can be achieved to a certain extent.

The heat exchanger has been described as being used as a radiator of an engine of an automotive vehicle for dissipating heat from engine cooling water. However, the heat exchanger is not limited to a radiator of the type described and may be used as a heat dissipator for warm water suitable for use with heating equipment for houshold use or for use in a motor vehicle, or in many other applications.

From the foregoing description, it will be appreciated that the heat exchanger comprises a tube of a flat cross-sectional shape formed with a multiplicity of projections arranged in strip form in a direction that intersects the axis of the tube at least on a surface thereof on which the tube is in thermal contact with corrugated fins. By virtue of this feature, the tube has its strength greatly increased and the endurance strength of the tube can be greatly increased by using material of a small thickness for making the tube while at the same time improving the efficiency with which heat exchange takes place. Formation of the projections increases the surface area of the tube, thereby to further increase heat exchanging efficiency.

The projections formed on the surface of the flat tube each extend by less than the thickness of the wall of the tube which is small enough, as compared with the minor dimension of the tube, not to make it necessary to pay special attention to the position of the projections when the tube is joined to the corrugated fins. Thus fabrication of the heat exchanger is facilitated.

CLAIMS

1. A heat exchanger comprising:
a tube (3) of a flat cross-sectional shape formed of metal and permitting a heat exchanging medium to flow therethrough;
fins (5) in thermal contact with said tube (3) for promoting exchange of heat between the heat exchanging medium and a fluid; and
a multiplicity of projections (3A) formed on one side of said tube (3) and arranged in a direction intersecting the axis of said tube (3), said projections (3A) each extending from said tube (3) by a distance less than the thickness of a wall of said tube (3).

2. A heat exchanger as claimed in claim 1 wherein said fins (5) are joined by welding to said tube (3) along the major dimension thereof.

3. A heat exchanger as claimed in claim 1 wherein said projections (3A) are each in the form of a triangle in cross section.

4. A heat exchanger as claimed in claim 1 wherein said projections (3) are each in the form of an arc in cross section.

5. A heat exchanger as claimed in claim 1 wherein said projections (3A) are each in the form of a trapezoid in cross section.

6. A method of fabricating a heat exchanger comprising the steps of:
successively forming on a planar metal strip (10) a multiplicity of projections (3A) each extending from said strip (10) by a distance less than the thickness of said strip (10) in such a manner that said projections (3A) are arranged in a direction intersecting the axis of said strip (10);
bending said strip (10) with said projections (3A) into a cylindrical shape and then seaming the cylindrical body;
applying solder to the seamed cylindrical body and finishing the soldered cylindrical body in the form of a flat tubular body (3); and
joining by welding corrugated fins (5) to said flat tubular body (3) along its axis.

FIG. 1

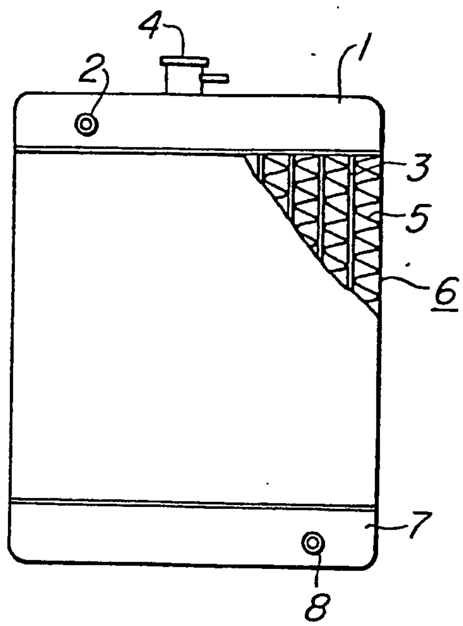

FIG. 2

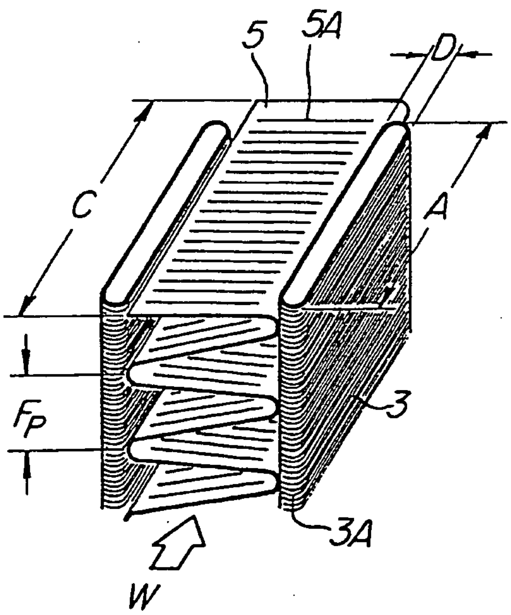

FIG. 3

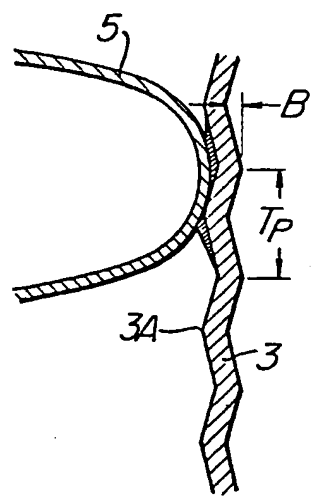

FIG. 4

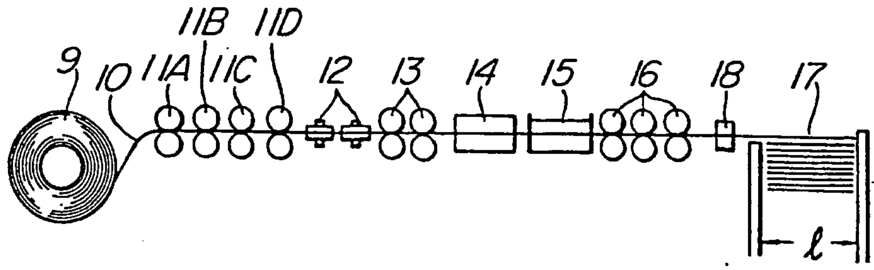

FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

FIG. 5E

FIG. 5F

FIG. 6

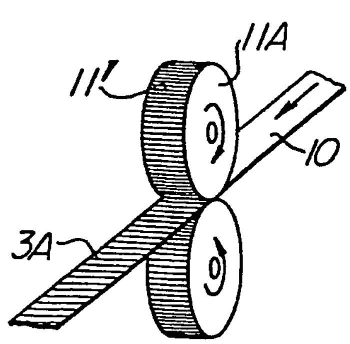

FIG. 7

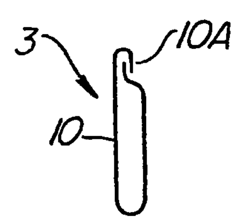

FIG. 8

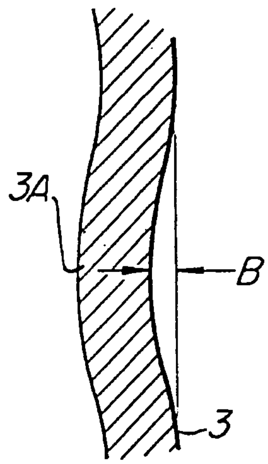

FIG. 9

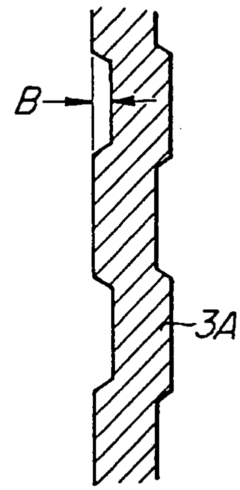

FIG. 10

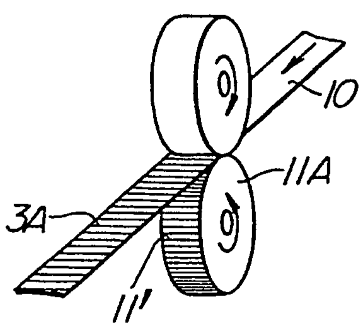

FIG. 11

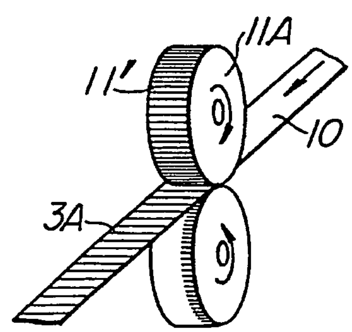

FIG. 12

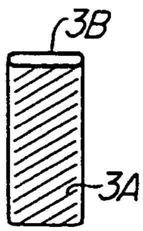

FIG. 13

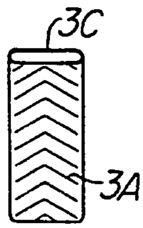

FIG. 14

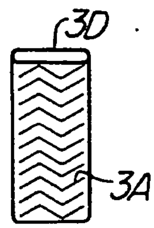

FIG. 15

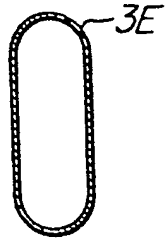

FIG. 16

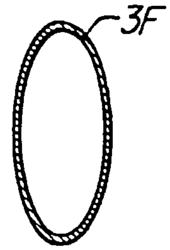

FIG. 17

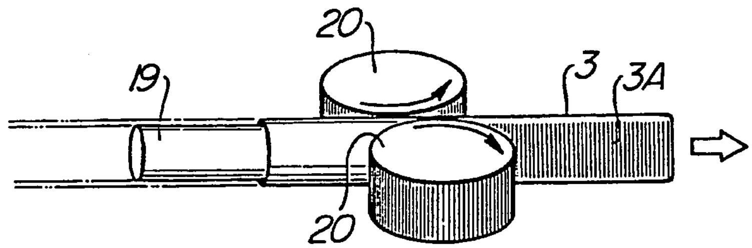

FIG. 18